GT ENGINEERING

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California Building Standards Commission
915 Capitol Mall, Suite 200
Sacramento, CA 95814

RE: Use of PEX for potable water plumbing

Chair and Members of the Commission:

At the behest of the California Pipe Trades Council, I have been requested to submit this letter regarding my experience with failures in cross-linked polyethylene (PEX) piping. By way of personal background, my education includes a Ph.D. from the University of California at Berkeley in Materials Science and Engineering. For the past 28 years I have been continuously employed in materials research and failure analysis. Since 1988 my work has concentrated on forensic analysis of materials failures, serving as an expert consultant to manufacturers, industry, the Federal Government and the insurance industry. On numerous occasions I have been retained by legal counsel and have provided expert testimony on issues involving degradation and/or failure of materials. Many of these cases have involved failures in polymers and plastics and specifically PEX piping.

In this letter I address my personal experience with massive failures of PEX piping that has been the subject of numerous lawsuits in Washington State and is a matter currently the subject of efforts to establish a class action against the manufacturer. It is my belief that while the Washington State failures involve a single manufacturer, the issues revealed as a result of these losses are not solely limited to the batch of pipe involved in these failures. These failures demonstrate that PEX pipe may potentially prematurely fail if exposed to a number of commonly encountered materials and environmental conditions, including chlorine, sunlight, metal ions, high temperatures and solvents including those in some firestopping material. Further study of the sensitivity of PEX to failing when exposed to these materials and conditions should be considered in order that appropriate mitigations and limitation on the use of this product may be imposed.

PEX is a generic label applying to a whole range of PEX pipes, accordingly the sensitivity of PEX pipe to these materials and conditions may vary widely depending on the manufacturing process and the stabilizing additives added. While improvements to this product are continually being implemented, the State of California is contemplating generic approval of PEX, rather than approval of a specific version of PEX. While NSF and ASTM standards provide some assurance of quality, these standards do not eliminate the possibility of premature failures. These industry standards are limited in scope and do not fully reflect real life applications.

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<u>Response to HCD Literature Search</u>
First, allow me to comment on the "HCD Literature Search Concerning on the Use of PEX as Potable Water Pipe" dated February, 2004. In my opinion there are a number of shortcomings and errors in this document.

In section A1 there is an attempt to distance PEX from historical polybutylene (PB) failures. Both of these materials belong to the same plastic family, referred to as polyolefins. In addition polypropylene (PP) is another polyolefin. Many are familiar with the widespread failures and subsequent litigation involving PB. The massive failure of PP water heater dip tubes was also the subject of a nation-wide recall a couple years ago, with on-going litigation between the water heater manufacturers and the supplier of the dip tubes. I am an expert consultant involved in this litigation. The fact is that all polyolefins are inherently unstable in heated water and require the presence of stabilizing additives to maintain long term integrity. The issues in PEX, PB and PP potable water piping applications are all similar, loss or consumption of the stabilizer package leads to failure of the piping.

In section A2 it is stated that PEX is not subject to attack by chlorine in water. This is simply incorrect. Chlorine is a strong oxidizer. Its presence in most domestic potable water causes the oxidative loss of stabilizers in the PEX which, upon depletion, leads to relatively short term degradation of the PEX molecular matrix and pipe failure. This is why a new stronger standard has been enacted (ASTM F 2023-04) in an attempt to alleviate the issue of chlorine-induced failures in PEX piping. This standard, however, only addresses the singular issue of pipe longevity under the specific test protocol. PEX pipe meeting the new chlorine standard may still fail due to chlorine exposure where it has also suffered significant stabilizer loss due to other factors.

In section A4 there is reference to a law suit involving PEX failures in a condominium complex in Seattle. The statement "only 19 of the 57 units experience (sic) water damage do (sic) to the PEX mechanical failures" is ludicrous as well as entirely misleading. First, this represents a 33% failure rate, which no one could conceivably believe is acceptable. Second, as provided in detail below, all of the tubing from the same PEX resin in these residences was highly deteriorated and would shortly have failed. More didn't fail because the residents shut down and isolated their hydronic heating systems until the piping was replaced. I know this for a fact because my laboratory tested piping samples from throughout the condominium complex.

<u>Massive Failures in PEX Tubing</u>
There have been, or are about to be, massive failures in PEX piping. In Washington State, I have been personally involved in the analysis of PEX piping that is failing in 9 multifamily residential complexes (condominiums, town homes and apartments). These complexes currently account for over 200 residential units. Through discovery in the litigation involving these failures I have become aware of similar failures in Canada, though my company has not independently evaluated the causes of the Canadian failures.

The above failures all involve piping manufactured by a single vendor, Plasco Manufacturing, Ltd. (Plasco), labeled as UltraPEX™ and identified as Lot 7. Lot 7 means that the tubing originated from a single resin source, Flexet™ 5100 resin/Flexet™ 725 catalyst that was originally distributed by AT Plastics Inc, which was subsequently purchased by Noveon. UltraPEX is PEXb produced by the silane cross-linking process. It is my understanding that there are several additional PEXb manufacturers that were or are using the same resin. There were millions of feet of Lot 7 UltraPEX distributed throughout the United States.

The Washington State failures have all occurred in open loop hydronic heating systems, with failures starting as soon as 2 to 3 heating seasons. The susceptibility of PEX pipe to failure, however, is not limited to open loop hydronic systems. Failures in at least one of the Canadian locations were occurring in hot potable water lines.

UltraPEX tubing was warranted by the manufacturer for 25 years. Plasco was purchased by Uponor (also owner of Wirsbo) in 1998. Recently Wirsbo shut down both its Plasco and RTI PEXb piping operations.

<u>Time to Failure</u>
The Commission's evaluation of the potential impacts of PEX should include consideration of the material's longevity in actual allowed service, as well as what happens upon failure.

Such evaluation must go beyond mere compliance with ASTM and NSF requirements. Our laboratory studies, for example, demonstrated that UltraPEX Lot 7 pipe under near ideal conditions for open-loop hydronic heating would be depleted of all failure inhibiting stabilizer in 8 to 10 years. This product was produced from 1996 to 1999. The product was also listed as conforming to the requirements of ASTM F876[1], the primary standard for PEX tubing, ASTM F877[2] and being in conformance with NSF requirements for potable water application NSF-pw (NSF 14[3] and 61[4]) at the time of manufacture. The failure of the UltraPEX pipe demonstrates that conformance with ASTM and NSF standards does not, in itself, guarantee that this material will not prematurely fail in a manufacturer allowed application.

The potential scope of damage from PEX failures must also be assessed. PEX failures may be more likely than copper pipe failures to cause catastrophic damage. One of the problems with PEX is that the material embrittles; failure, thus, typically results in a large catastrophic break. My experience with copper piping is that corrosive failure generally

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[1] ASTM F876 Standard Specification for Crosslinked Polyethylene (PEX) Tubing
[2] ASTM F877 Standard Specification for Crosslinked Polyethylene (PEX) Plastic Hot- and Cold-Water Distribution Systems
[3] ANSI/NSF 14 Plastics Piping System Components and Related Materials
[4] ANSI/NSF 61 Drinking Water system Components – Health Effects

leads to localized penetration that provides a limited volume leak through a pin hole or small crack.

Sensitivity to Firestopping Material

Initial failures of UltraPEX piping in the Washington State cases were noted where intumescent firestop material was in contact with the pipe. The Plasco installation instructions of the period did not forbid the use of the firestop and the firestop material was specifically labeled as safe for use with PEX pipe. Our analysis showed that pipe under the firestop material was completely depleted of stabilizers, as determined by oxidation induction time (OIT) testing per ASTM D3895[5]. Fourier Transform Infrared (FTIR) spectroscopy showed that only traces of a solvent from the firestop could be identified penetrating the PEX. However, this was apparently sufficient to degrade the pipe. The pipe had turned yellow and become embrittled resulting in axial and circumferential cracking. When OIT tests were conducted in piping away from the firestop region it was discovered that the stabilizer package in the material had been substantially depleted throughout the pipe.

It should be noted that while exposure to firestopping accelerated the failure of the PEX piping, it was not the sole cause for degradation of the piping. Similar findings were found in each of the complexes using the Plasco Lot 7 pipe, even in those complexes where firestop was not employed. Thus, I believe we are witnessing the tip of the iceberg as far as failures are concerned, discovered incidentally because of the application of a particular firestop material.

PEX Sensitivity to UV Light

Our own experiments showed that Plasco UltraPEX tubing was virtually devoid of residual effective stabilizer after two weeks of rooftop exposure in sunny Seattle. This contradicted implications in the product literature that with exposure of no more than 30 days the product should have been serviceable for the 25-year warranty period.

It is my experience that several PEX piping producers have instituted improvements in packaging because of sensitivity to UV degradation of their product. While this may address transportation and storage exposure it does not provide assurance that product is protected at the jobsite. Furthermore, such UV protective packaging is not required by ASTM or NSF.

Literature from PEX piping producers warns against UV exposure, but I have never seen any data that quantifies exposure to the loss of product longevity. I believe this would be important information to have in assessing the permitted application of PEX piping, since my experimental observation is that upward of 7 to 8% of product life may be lost per day of exposure.

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[5] ASTM D3895 Standard Test Method for Oxidative-Induction Time of Polyolefins by Differential Scanning Calorimetry.

Defense Positions

Statements by Plasco's key employees, including their director of quality of control, were that the product was made in accordance with the applicable standards, implying this made the material serviceable. An important point was that no one at Plasco actually knew anything about the material. The tubing manufacturer had no information on the stabilizer package in the Flexet resin/catalyst, hence in the UltraPEX tubing being manufactured from the resin. Further, the manufacturer had conducted no independent service testing of their product, aside from the standards compliance testing.

There had been numerous early failures, prior to the mass failures in Washington State. These had all been attributed to ultraviolet (UV) light exposure, allegedly at the responsibility of the purchaser. While UV light may lead to failure of PEX piping, our assessment of post-failure analysis conducted at the manufacturer showed that there was no validity in their testing for isolating UV damage versus other mechanisms leading to embrittlement.

Legal defense in the Washington State cases has concentrated on issues with the design and installation of the affected hydronic heating systems, and piping product compliance with regulatory standards. I will address standards compliance testing in the next section. The hydronic heating systems at issue were all of open loop design. In this design heating water is intermixed with potable water in a common domestic water heater or boiler. Thus, the heating system PEX pipe is continuously exposed to refreshed oxygenated and chlorinated water, same as occurs in potable water systems. This is an allowed, even promoted, design in Plasco literature. The defense indicates this allowed use promotes degradation through exposure to oxidizers; time of exposure and temperature are also factors.

Other issues brought up in defense are exposure to ferrous metals and/or mixed metals in the piping systems attached to the PEX tubing. They argue that metal ions of copper and iron promote oxidation of the PEX. Surely the Commission should recognize that potable water for domestic consumption will be oxygenated, will most likely contain chlorine, and will be subject to the presence of metal ions both from the water sources and from water transmission systems. This admission raises a fair argument that installation of PEX piping in a remodel or repair to a residence with copper or iron pipes may contribute to premature failure of the PEX pipe. The Commission should question the PEX piping industry regarding data on the sensitivity to PEX degradation in the presence of metal ions and corrosion product.

Standards Conformance and Testing – What Does it Mean

ASTM F 876[6] is the primary standard addressing PEX tubing. This standard was first published in 1984. There have been 23 versions of the standard including the current issuance. Only starting in the 2002 version was chlorine resistance testing mandated. It

[6] ASTM F876 Standard Specification for Crosslinked Polyethylene (PEX) Tubing

is obvious that the PEX standard has been highly evolutionary, addressing issues, such as failures in chlorinated water, as they have arisen. ASTM F 876 references into PPI TR-3[7] for hydrostatic design stresses. PPI TR-3 then references into ASTM D2837[8] for the test method to obtain an extrapolated 100,000 hour (11.4 year) design life. This whole procedure utilizes accelerated methods (elevated temperature and pressure) to obtain extrapolated lifetimes.

The methodology inherently assumes that the properties of the piping material do not change over time. However, with materials such as PEX, extended service lifetimes depend on the continued availability of the stabilizer package.

The most extensive research conducted on polyolefins, including PEX, was a long-term program at Studsvik AB, Sweden. This work showed that the stabilizers are subject to both consumption and loss due to leaching from the pipe, both internally and externally.[9] Thus, conformance to standards based on accelerated testing does not guarantee viability under extended service usage.

More stringent testing, such as ASTM F-2023-04[10] has only recently been developed to address obvious problems with failures in chlorinated water. This standard seeks to provide assurance of a 50-year lifetime. However, similar to other test standards this one contains the following caveat:

> "The performance of a material or piping product under actual conditions of installation and use is dependent upon a number of factors including installation methods, use patterns, water quality, nature and magnitude of localized stresses, and other variables of an actual, operating hot-and-cold water distribution system that are not addressed in this test method. As such, the extrapolated values do not constitute a representation that a PEX tube or system with a given extrapolated time-to-failure value will perform for that period of time under actual use conditions."

One should also note that ASTM F-2023-04 only provides a PEX lifetime assessment for water disinfectant systems using free-chlorine. Note 1 in the standard states "Disinfecting systems other than chlorine have not been evaluated by this method." The other methods mentioned include chlorine dioxide, ozone, and chloramines.

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[7] PPI Technical Report TR-3/92 Policies and Procedures for Developing Recommended Hydrostatic Design Stresses for Thermoplastic Pipe Materials.

[8] ASTM D2837 Test Method for Obtaining Hydrostatic Design Basis for Thermoplastics Pipe Materials

[9] Smith, G.D. et al, Modeling of Antioxidant Loss From Polyolefins in Hot-Water Applications. I: Model and Application to Medium Density Polyethylene Pipes. Polymer Engineering and Science, May 1992, V.32, No. 10 p. 658

[10] ASTM F-2023-04 Standard Test Method for Evaluating the Oxidative Resistance of Crosslinked Polyethylene (PEX) Tubing and Systems to Hot Chlorinated Water

Based on the above, as well as our direct experience with PEX piping, it becomes obvious that manufacturing to existing codes and standards provides only limited information on the relative serviceability of the product under the chosen test conditions. Importantly, there do not currently appear to be standards or tests that address the effects of the multitude of environmental contaminants or challenges that may affect the PEX product from the outside. For example, should there be some minimum longevity to UV exposure? The UltraPEX pipe we tested was very sensitive to permeation and loss of integrity in the presence of minute amounts of organic solvents. Many household products, for example pesticide sprays, may have an organic carrying agent. For a potable water application it would appear reasonable to understand and regulate the permeability as well as continued integrity of piping to potentially hazardous environmental conditions.

Furthermore, NSF and ASTM standards do not address the cumulative effects of exposure to environmental conditions and contaminants that may affect the longevity of PEX. For example, our tests have shown that just a few days of exposure to the sun may dramatically reduce the amount of the antioxidants available to protect PEX pipe from expected exposure to chlorine.

<u>Alternative Forms of PEX Piping</u>

Another form of PEX piping is the PEX-AL-PEX configuration. This design has a thin layer of aluminum (Al) sandwiched between inner and outer layers of PEX. The PEX on this composite material may be subject to the same degradation issues as the singular PEX piping. The thin Al layer serves as a diffusion barrier and would provide structural reinforcement. I am not personally aware of whether this particular product has UV protection in the outer PEX layer, though the Al layer will limit the depth of degradation. Further study or disclosure by the manufacturer is needed to assess the mechanical stability of PEX-AL-PEX when its PEX layers become devoid of stabilizer and embrittle.

<u>Significance to California Building Standards</u>

I believe that the above information presents a fair argument that PEX piping may be susceptible to premature failure even when it complies with minimum NSF and ASTM standards. This potential for failure is significant and should be considered by the California Building Standards Commission in their deliberations concerning application of PEX piping for several reasons:

1. There are significant numbers of failures of PEX material in potable hot water applications. Through a set of circumstances that led to particularly early failures in a number of Washington State residences, we were led to the early discovery of what I believe will almost certainly become a massive loss of serviceability of PEX pipe. While the losses we are knowledgeable about trace to a single manufacturer, there apparently were multiple manufacturers of PEX pipe that are using the same resin.

2. Furthermore, the failures have revealed weaknesses in PEX generally that may not be limited to just this particular resin. These failures demonstrate that PEX pipe may potentially prematurely fail if exposed to a number of commonly encountered materials and environmental conditions, including chlorine, sunlight, metal ions, high temperatures, petroleum products and firestopping material. Further study of the sensitivity of PEX to failing when exposed to these materials and conditions should be considered in order that appropriate mitigations and limitation on the use of this product may be imposed.

3. A manufacturer's claim that piping is manufactured to be compliant with all the applicable ASTM and NSF standards is insufficient to assure long-term serviceability. This is true for service under intended exposure environments. There is no testing under the applicable standards to which PEX pipe is certified that assures serviceability and safety under conditions of unintended or credible accidental exposure.

4. At least some PEX pipe manufacturers have no inherent knowledge of the properties or resistance of their product. These manufacturers totally rely on the information imparted to them by their resin suppliers. The information provided by the resin suppliers, even through numerous routes of legal discovery, has been very limited and does not typically include quantitative test data to support safety evaluations of the product in an adverse environment.

5. PEX piping is not a single, uniform, product. There are undoubtedly some superior performing products along with those that likely will not provide a serviceable product for a reasonable structural life expectancy. The foremost problem facing the user, and the regulator, is the lack of access to data that provides a basis for decisions on individual product adequacy. Unlike a material such as copper pipe, where conformance to ASTM specifications does denote a consistency in product performance, the performance of PEX piping is not an inherent feature of the material. Rather it depends on the stabilizers, the types, amounts, and relative amounts, which are added to maintain the integrity of the structural backbone of the plastic. The design of particular stabilizer packages are considered highly proprietary and often rests not with the pipe manufacturer but with those companies formulating the resins used in the extrusion of PEX piping.

6. There should be concern about the inherent weaknesses of some PEX products. The material is inherently subject to diffusion of classes of chemicals that may prove injurious should they reach potable water service. Much of the material currently in service has not been UV stabilized, therefore suffers from performance loss subject to the vagueness of construction site protection. There are methods, both in terms of physical design and the addition of diffusion barriers, that may preclude problems, but these are not necessarily present in the broad definition of PEX piping that meets current standards. Based on my experience, many PEX piping manufacturers will not be able to provide data on the behavior of their product under conditions of exposure that regulators should consider for safety of the public water supply, such as when pesticides are applied where they may come in contact with residential piping.

Before the California Building Standards Commission approves application of PEX for potable water systems it would appear prudent that further assessment be conducted. In my opinion the process needs to include a definition of hazards, determination of appropriate testing that will assure adequate resistance to identified hazards, and definition of what information manufacturers and suppliers need to develop to assure an adequately safe and serviceable product.

Sincerely,
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